Molnár, L.; Pál, A.; Sáneczky, K.; Szabó, R.; Vinkó, J.; Szabó, Gy.M.; Kiss, Cs.; Hanyecz, O.; Marton, G.; Kiss, L.L. (2018) "Main-belt Asteroids in the K2 Uranus Field." *Ap. J. Supp. Ser.* **234,** A37

Pál, A.; Szakáts, R.; Kiss, C.; Bódi, A.; Bognár, Z.; Kalup, C.; Kiss, L.L.; Marton, G.; Molnár, L.; Plachy, E.; Sárneczky, K.; Szabó, G.M.; Szabó, R. (2020). "Solar System Objects Observed with TESS - First Data Release: Bright Main-belt and Trojan Asteroids from the Southern Survey." *Ap. J.* **247**, A26.

Pravec, P.; Wolf, M.; Sarounova, L. (2008web). *http://www.asu.cas.cz/~ppravec/neo.htm*

Pravec, P.; Scheirich, P.; Durech, J.; Pollock, J.; Kusnirak, P.; Hornoch, K.; Galad, A.; Vokrouhlicky, D.; Harris, A.W.; Jehin, E.; Manfroid, J.; Opitom, C.; Gillon, M.; Colas, F.; Oey, J.; Vrastil, J.; Reichart, D.; Ivarsen, K.; Haislip, J.; LaCluyze, A. (2014). "The tumbling state of (99942) Apophis." *Icarus* **233**, 48-60.

Stephens, R.D. (2016a). "Asteroids Observed from CS3: 2016 January-March." *Minor Planet Bull*. **43**, 252-255.

Stephens, R.D. (2016b). "Asteroids Observed from CS3: 2016 April - June." *Minor Planet Bull*. **43**, 336-339.

Stephens, R.D. (2018). "Asteroids Observed from CS3: 2018 January - March." *Minor Planet Bull*. **45**, 299-301.

Stephens, R.D.; Warner, B.D. (2019). "Main-belt Asteroids Observed from CS3: 2019 April to June." *Minor Planet Bull*. **46**, 449-456.

Tonry, J.L.; Denneau, L.; Flewelling, H.; Heinze, A.N.; Onken, C.A.; Smartt, S.J.; Stalder, B.; Weiland, H.J.; Wolf, C. (2018). "The ATLAS All-Sky Stellar Reference Catalog." *Astrophys. J.* **867**, A105.

Warner, B.D. (2006). "Asteroid lightcurve analysis at the Palmer Divide Observatory: July-September 2005." *Minor Planet Bull*. **33**, 35-39.

Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2020 Oct. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2013). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2013 January - March." *Minor Planet Bull*. **40**, 137-145.

Waszczak, A.; Chang, C.-K.; Ofek, E.O.; Laher, R.; Masci, F.; Levitan, D.; Surace, J.; Cheng, Y.-C.; Ip, W.-H.; Kinoshita, D.; Helou, G.; Prince, T.A.; Kulkarni, S. (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry." *Astron. J.* **150**, A75.

PERIOD DETERMINATIONS FOR SEVENTEEN MINOR PLANETS

Tom Polakis
Command Module Observatory
121 W. Alameda Dr.
Tempe, AZ 85282
tpolakis@cox.net

(Received: 2020 Dec 28)

Phased lightcurves and synodic rotation periods for 17 main-belt asteroids are presented, based on CCD observations made from 2020 October through 2020 December. All the data have been submitted to the ALCDEF database.

CCD photometric observations of 17 main-belt asteroids were performed at Command Module Observatory (MPC V02) in Tempe, AZ. Images were taken using a 0.32-m f/6.7 Modified Dall-Kirkham telescope, SBIG STXL-6303 CCD camera, and a 'clear' glass filter. Exposure time for all the images was 2 minutes. The image scale after 2×2 binning was 1.76 arcsec/pixel. Table I shows the observing circumstances and results. All of the images for these asteroids were obtained between 2020 October and 2020 December.

Images were calibrated using a dozen bias, dark, and flat frames. Flat-field images were made using an electroluminescent panel. Image calibration and alignment was performed using MaxIm DL software.

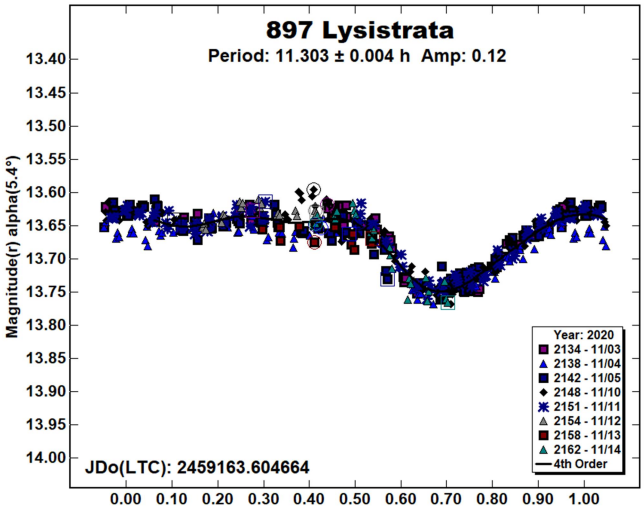
The data reduction and period analysis were done using MPO Canopus (Warner, 2020). The 45′×30′ field of the CCD typically enables the use of the same field center for three consecutive nights. In these fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected with colors within the range of $0.5 < B\text{-}V < 0.95$ to correspond with color ranges of asteroids. In order to reduce the internal scatter in the data, the brightest stars of appropriate color that had peak ADU counts below the range where chip response becomes nonlinear were selected. MPO Canopus plots instrumental vs. catalog magnitudes for solar-colored stars, which is useful for selecting comp stars of suitable color and brightness.

Since the sensitivity of the KAF-6303 chip peaks in the red, the clear-filtered images were reduced to Sloan r′ to minimize error with respect to a color term. Comparison star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into MPO Canopus. The ATLAS catalog derives Sloan griz magnitudes using a number of available catalogs. The consistency of the ATLAS comp star magnitudes and color-indices allowed the separate nightly runs to be linked often with no zero-point offset required or shifts of only a few hundredths of a magnitude in a series.

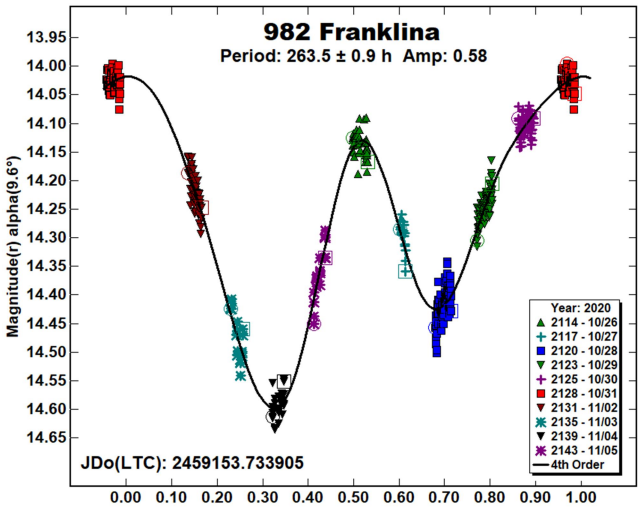
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall data quality including errors from the calibration of the frames, measurement of the comp stars, the asteroid itself, and the period-fit. Period determination was done using the MPO Canopus Fourier-type FALC fitting method (cf. Harris et al., 1989). Phased lightcurves show the maximum at phase zero. Magnitudes in these plots are apparent and scaled by MPO Canopus to the first night.

Most asteroids were selected from the CALL website (Warner, 2011a) using the criteria of magnitude greater than 15.5 and quality of results, U, less than 2+. In this set of observations, 6 of the 17 asteroids had no previous period analysis, 1 had U = 1, and 9 had U = 2. The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results. All the new data for these asteroids can be found in the ALCDEF database.

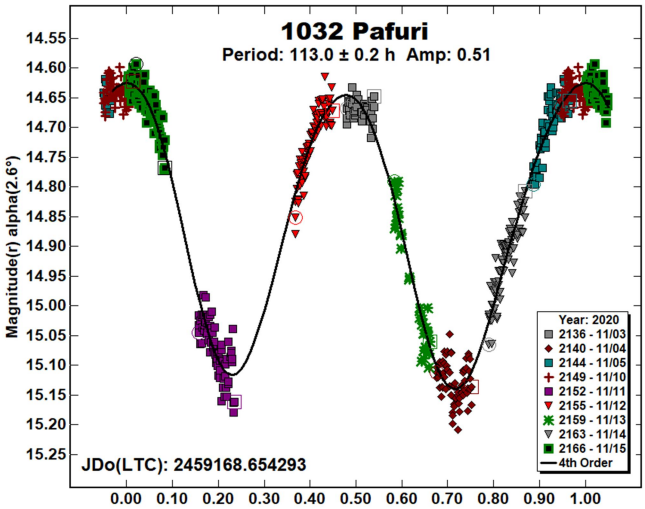
897 Lysistrata is a Eunomia-family asteroid, discovered by Max Wolf at Heidelberg in 1918. Kim (2014) published a rotational period of 11.26 ± 0.05 h, and Mas (2018) shows 11.275 ± 0.009 h. During eight nights, 458 images were gathered, producing a period of 11.303 ± 0.004 h, in agreement with previous values. The lightcurve has an amplitude of 0.12 mag. with an RMS error of 0.001 mag.



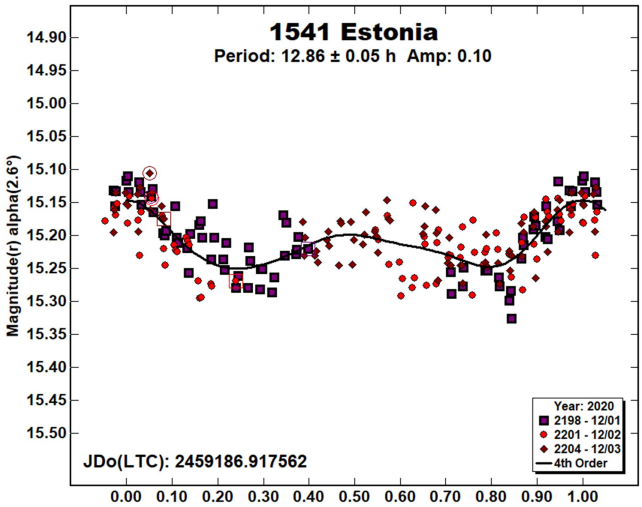
982 Franklina. This outer main-belt asteroid in an eccentric orbit was discovered at Heidelberg in 1922 by H.E. Wood. Behrend (2020) computed a period of 41.5 ± 0.1 h, and Pál (2020) obtained 186.48 ± 0.05 h. In ten nights, 477 data points were used to calculate a period of 263.5 ± 0.9 h, with an amplitude of 0.58 ± 0.021 mag. The period spectrum did not show matches at the previously published periods.



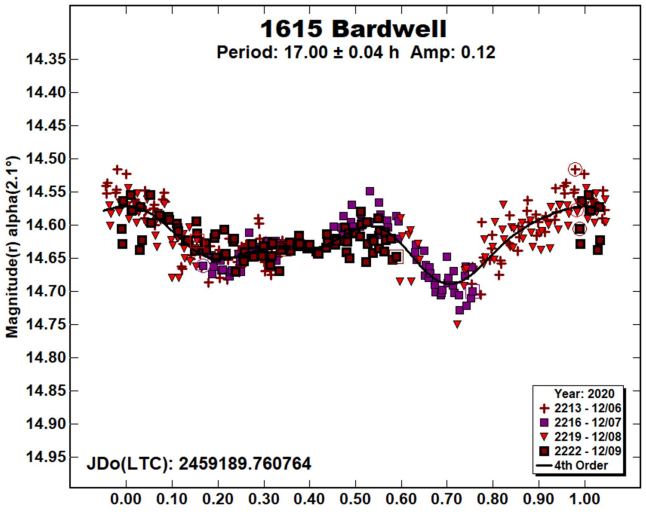
1032 Pafuri is also an H.E. Wood discovery, made in 1924 at Heidelberg. Ditteon (2019) shows a good fit to a period of 33.39 ± 0.03 h. A total of 581 data images obtained during nine nights were used to calculate a period solution of 113.0 ± 0.2 h, disagreeing with Ditteon's assessment. The amplitude of the lightcurve is 0.51 ± 0.026 mag, which is much larger than the previously published amplitude.



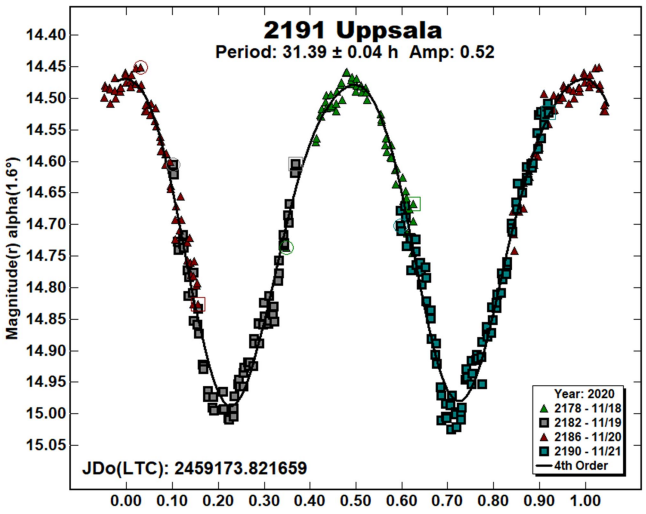
1541 Estonia was discovered at Turku in 1939 by Yrjö Väisälä. The LCDB shows only one period of 10.1 ± 1.0 h derived by Behrend (2015). After three nights, 211 images were collected. The period spectrum shows a weak signal at the bimodal solution of 12.86 ± 0.05 h, disagreeing with Behrend's result. The RMS error of 0.032 mag. is significant relative to the amplitude of 0.10 mag.



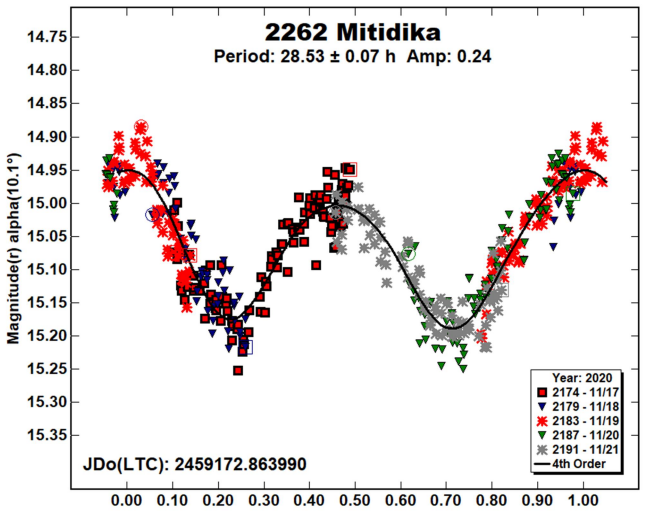
1615 Bardwell is a Themis-family asteroid that came to a favorable opposition in 2020. It was discovered at Goethe Link Observatory in 1950. The single period in the LCDB dates back to 1979, when Tedesco (1979) calculated >18 h. A total of 339 images taken during four nights produced a period solution of 17.00 ± 0.04 h, with an amplitude of 0.12 ± 0.023 mag.



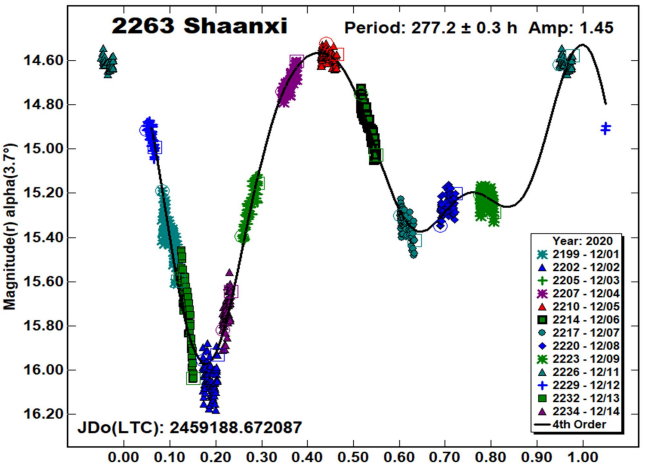
2191 Uppsala. This Eos-family asteroid was discovered by C.I. Lagerqvist at Mt. Stromlo in 1977. No period solutions appear in the LCDB. Over a four-night interval, 302 images were obtained, yielding a synodic period of 31.39 ± 0.04 h. The amplitude is 0.52 mag., with an RMS error on the fit of 0.026 mag.



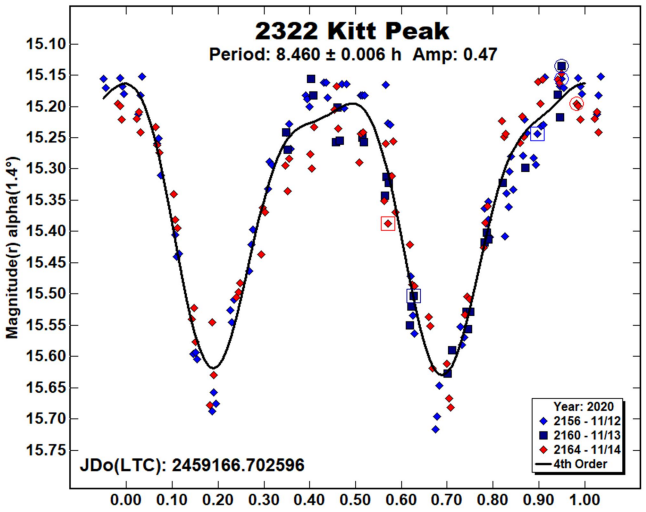
2262 Mitidika lies in a very eccentric orbit which brought it to a favorable opposition in 2020. It was discovered Paul Wild at Zimmerwald in 1978. Pál (2020) shows a period of 28.0933 ± 0.0005 h. During five nights, 440 images were used to compute a period of 28.53 ± 0.07 h, in agreement with Pál's value. The amplitude is 0.24 mag., with an RMS error on the fit of 0.032 mag.



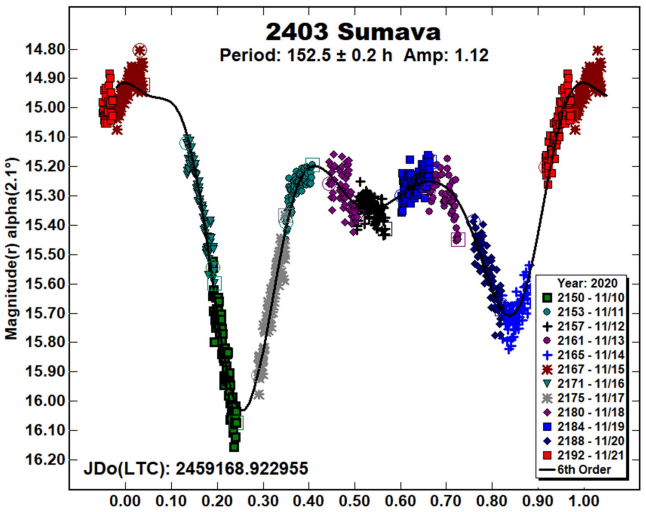
2263 Shaanxi was discovered in 1978 at Purple Mountain Observatory. Warner (2011b) published a period of 41.7 ± 0.1 h. A total of 988 data points were obtained in 13 nights. The period solution is 277.2 ± 0.3 h. The lightcurve features an extremely deep primary minimum, producing an amplitude of 1.45 ± 0.063 mag.



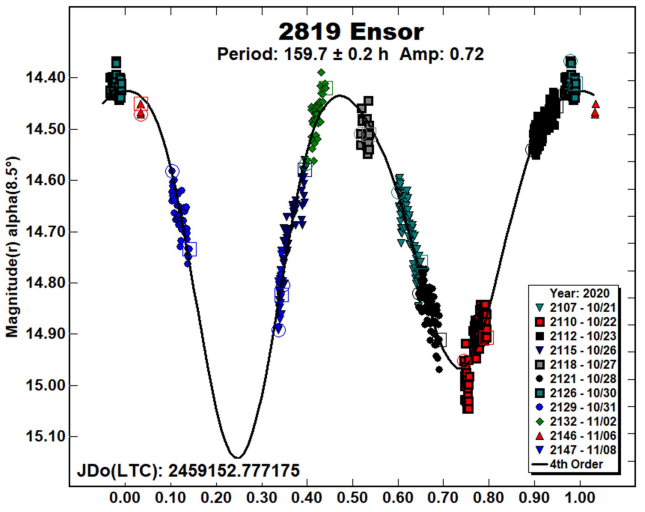
2322 Kitt Peak is a member of the Flora family, discovered at Goethe Link Observatory in 1954. No period solutions appear in the LCDB. Due to its short period and high amplitude, it was observed for only three nights, with 175 data points. The rotational period is 8.460 ± 0.006 h, with an amplitude of 0.47 ± 0.043 mag.



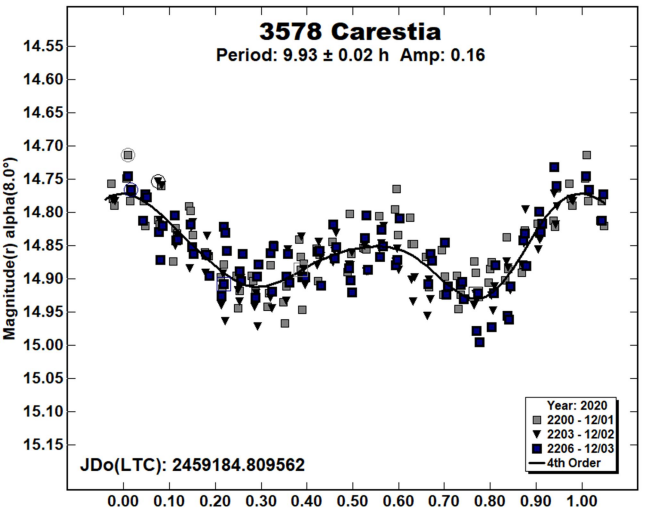
2403 Sumava. This minor planet was discovered in 1979 at Klet Observatory by Antonín Mrkos. No known period solutions exist. In a span of 12 observing nights, 911 images were taken. This produced a period solution of 152.5 ± 0.2 h, with a large amplitude of 1.12 ± 0.050 mag.



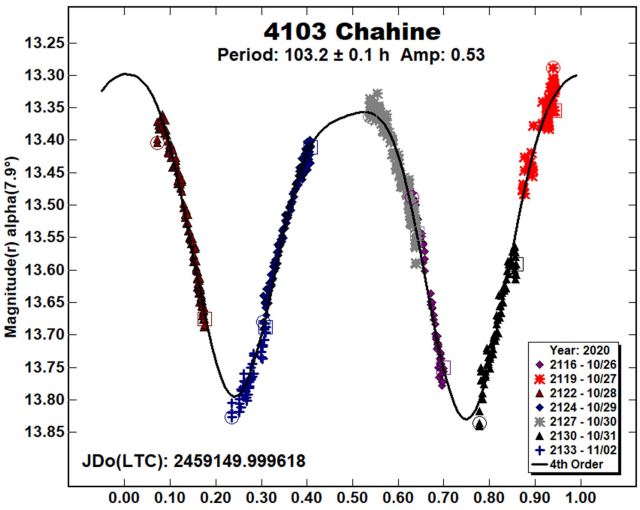
2819 Ensor lies in the outer main belt. It was discovered by Eugène Joseph Delporte at Uccle in 1933. The LCDB shows no period solutions. It was observed during a favorable opposition on 11 nights, and 541 images were obtained. The rotational period is 159.7 ± 0.2 h, with an amplitude of 0.72 ± 0.031 mag.



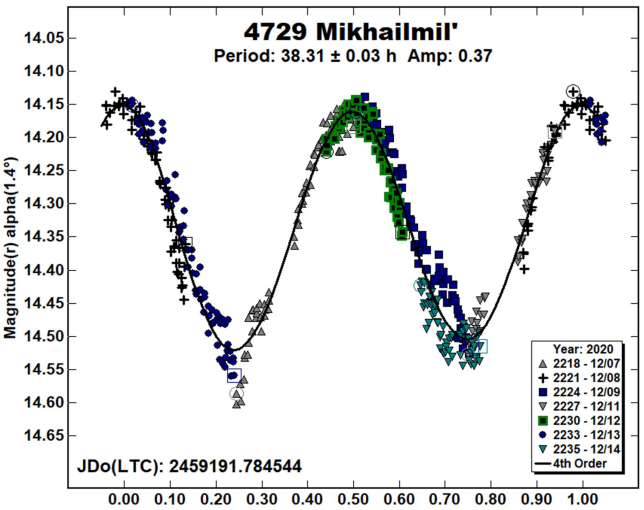
3578 Carestia occupies the outer main belt, in a highly inclined and eccentric orbit. Its discovery was made at Félix Aguilar Observatory in 1977 in El Leoncito. Holliday (1997) computed a period of 7.08 h, and Behrend (2008) calculated 9.93 ± 0.01 h. Three nights and 239 images were sufficient to calculate a period of 9.93 ± 0.02 h, in accordance with Behrend's value. The lightcurve has an amplitude of 0.16 ± 0.032 h.



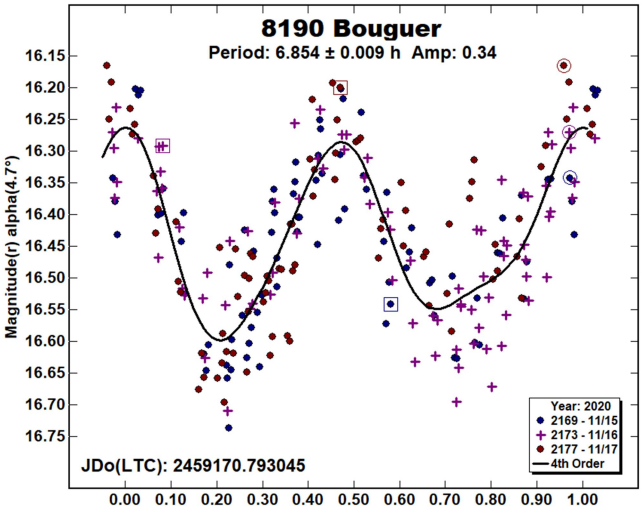
4103 Chahine. Eleanor Helin discovered this Phocaea-region asteroid in a highly inclined orbit in 1989 at Palomar Observatory. Behrend (2020) shows a period of 92.8 ± 0.3 h, and Pál (2020) published 105.161 ± 0.005 h. During seven nights, 642 images were secured. The rotation period is 103.2 ± 0.1 h, roughly agreeing with Pál. The amplitude is 0.53 mag., with an RMS error on the fit of 0.017 mag.



4729 Mikhailmil' is a member of the Flora family, discovered at Nauchnyj in 1980 by Lyudmila Vasilyevna. Ruthroff (2012) published a period of 17.74 ± 0.01 h. Over the course of seven nights, 485 images were obtained, yielding a synodic period of 38.31 ± 0.03 h, disagreeing with Ruthroff's value. The lightcurve has an amplitude of 0.37 ± 0.028 mag.



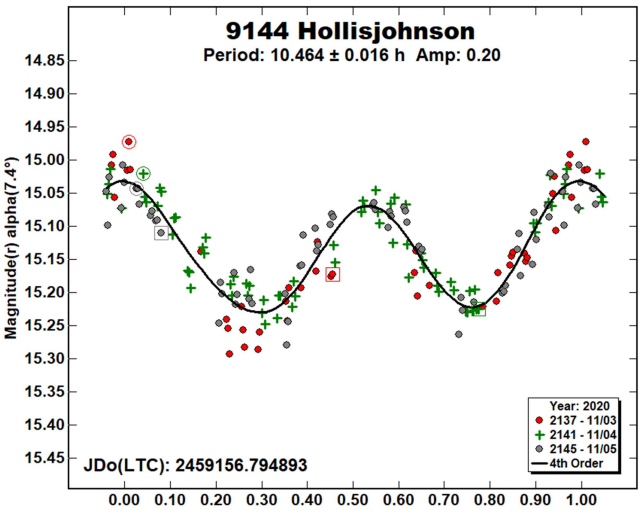
8190 Bouguer. Eric Walter Elst discovered this Flora-family minor planet in 1993. It was named after the mathematician Pierre Bouguer, sometimes called the father of photometry. Waszczak et al. (2015) published a period of 6.842 ± 0.0015 h. This asteroid serendipitously appeared in three frames with 2403 Sumava, so photometry was performed, despite it being a full magnitude fainter than the practical limit for this equipment and site. The 242 images were employed to calculate a rotational period of 6.854 ± 0.009 h, in good agreement with Waszczak. The amplitude is 0.34 mag., with a significant RMS error on the fit of 0.075 mag.



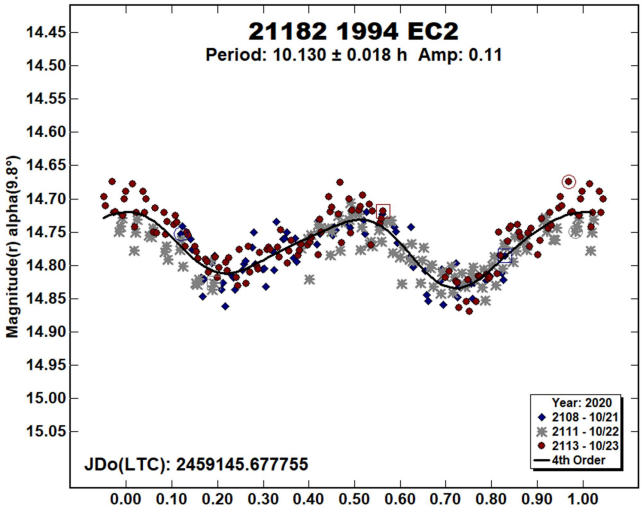
9144 Hollisjohnson was discovered at Goethe Link Observatory in 1955. Its highly eccentric orbit brought it to a favorable 2020 opposition. No period solutions have been published. Three nights and 171 data points were sufficient to produce a clean period solution of 10.464 ± 0.016 h. The amplitude is 0.20 ± 0.029 mag.

Number	Name	2020/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
897	Lysistrata	11/03-11/14	5.4,7.5	39	11	11.303	0.004	0.12	0.01	EUN
982	Franklina	10/26-11/05	9.5,11.0	15	17	263.5	0.9	0.58	0.02	MB-O
1032	Pafuri	11/03-11/15	*2.6,3.1	46	-6	113.0	0.02	0.51	0.03	MB-O
1541	Estonia	12/01-12/03	2.5,2.9	67	6	12.86	0.05	0.10	0.03	MB-O
1615	Bardwell	12/06-12/09	2.3.1.2	78	-2	17.00	0.04	0.12	0.02	THM
2191	Uppsala	11/18-11/21	1.7,0.7	59	2	31.39	0.04	0.52	0.03	EOS
2262	Mitidika	11/17-11/21	10.1,9.5	62	16	28.53	0.07	0.24	0.03	MB-I
2263	Shaanxi	12/01-12/14	3.6,8.8	61	2	277.2	0.3	1.45	0.06	EOS
2322	Kitt Peak	11/12-11/14	1.2,2.1	49	-2	8.460	0.006	0.47	0.04	FLOR
2403	Sumava	11/10-11/21	2.1,6.3	47	4	152.5	0.2	1.12	0.05	MB-I
2819	Ensor	10/21-11/08	8.4,16.2	14	0	159.7	0.2	0.72	0.03	MB-O
3578	Carestia	12/01-12/03	5.4,4.2	77	0	9.93	0.02	0.16	0.03	MB-O
4103	Chahine	10/26-11/02	*7.9,7.6	39	11	103.2	0.1	0.53	0.02	PHO
4729	Mikhailmil'	12/07-12/14	*1.6,3.0	78	0	38.31	0.03	0.37	0.03	FLOR
8190	Bouguer	11/15-11/17	4.5,5.6	47	4	6.854	0.009	0.34	0.08	FLOR
9144	Hollisjohnson	11/03-11/05	7.5,6.7	49	7	10.464	0.016	0.20	0.03	MB-I
21182	1994 EC2	10/21-10/23	9.5,11.1	17	6	10.130	0.018	0.11	0.02	PHO

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).



21182 1994 EC2 was discovered at Kitame in 1994 by Kin Endate. The LCDB shows no period solutions for it. A total of 285 images were taken during three nights. The computed synodic period is 10.130 ± 0.018 h, with an amplitude of 0.11 ± 0.022 mag.



Acknowledgements

The author would like to express his gratitude to Brian Skiff for his indispensable mentoring in data acquisition and reduction. Thanks also go out to Brian Warner for support of his MPO Canopus software package.

References

Behrend, R. (-2008, -2015, -2020). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Ditteon, R.; Weichang, L.; Sheerin, M. (2019). "Lightcurve Analysis of Minor Planets Observed at the Oakley Southern Sky Observatory: 2018 May-June." *Minor Planet Bull.* **46**, 276-276.

Harris, A.W.; Young, J.W.; Scaltriti, F.; Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

Harris, A.W.; Young, J.W.; Bowell, E.; Martin, L.J.; Millis, R.L.; Poutanen, M.; Scaltriti, F.; Zappala, V.; Schober, H.J.; Debehogne, H.; Zeigler, K.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Holliday, B. (1997). "Photometric Observations of Minor Planet 3578 Caresia." *Minor Planet Bull.* **24**, 1.

Kim, M.-J. et al. (2014). "Rotational Properties of the Maria Asteroid Family." *Astron. J.* **147**, 56-138.

Mas, V. et al. (2018). "Twenty-one Asteroid Lightcurves at Asteroids Observers (OBAS) - MPPD: Nov 2016 - May 2017." *Minor Planet Bull.* **45**, 76-82.

Pál, A.; Szakáts, R.; Kiss, C.; Bódi, A.; Bognár, Z.; Kalup, C.; Kiss, L.; Marton, G.; Molnár, L.; Plachy, E.; Sárneczky, K.; Szabó, G.; Szabó, R. (2020). "Solar System Objects Observed with TESS - First Data Release: Bright Main-belt and Trojan Asteroids from the Southern Survey." *Ap. J. Supl. Ser.* **247**, 26-34.

Ruthroff, J. (2012). "Lightcurve Analysis of 1786 Raahe and 4729 Mikhailmil'". *Minor Planet Bull.* **39**, 39.

Tedesco, E.F. (1979). "A photometric investigation of the colors, shapes and spin rates of Hirayama family asteroids." PhD Dissertation. New Mexico State University.

Tonry, J.L.; Denneau, L.; Flewelling, H.; Heinze, A.N.; Onken, C.A.; Smartt, S.J.; Stalder, B.; Weiland, H.J.; Wolf, C. (2018). "The ATLAS All-Sky Stellar Reference Catalog." *Astrophys. J.* **867**, A105.

Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2020 Aug. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2011a). Collaborative Asteroid Lightcurve Link website. *http://www.minorplanet.info/call.html*

Warner, B.D. (2011b). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: Unpublished Results from 1999 to 2008." *Minor Planet Bull.***38**, 89-92.

Warner, B.D. (2020). MPO Canopus software. *http://bdwpublishing.com*

Waszczak, A.; Chang, C.-K.; Ofek, E.O.; Laher, R.; Masci, F.; Levitan, D.; Surace, J.; Cheng, Y.-C.; Ip, W.-H.; Kinoshita, D.; Helou, G.; Prince, T.A.; Kulkarni, S. (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry." *Astron. J.* **150**, A75.